NASA TECHNICAL TRANSLATION

NASA TT F-14,916

SPACESHIPS

K. P. Feoktistov

Translation of: "Kosmicheskiye korabli", In: Naselennyy Kosmos (Inhabited Space) by B.P. Konstantinov, editor, Moscow, Nauka Press, 1972, pages 216-228.

(NASA-TT-F-14916) SPACESHIPS (Linquistic Systems, Inc., Cambridge, Mass.) 18 p
HC $3.00 CSCL 22B
N73-23867
Unclas
G3/31 03401

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 MAY 1973

STANDARD TITLE PAGE

1. Report No. NASA TT F-14,916	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SPACESHIPS		5. Report Date MAY 1973
		6. Performing Organization Code
7. Author(s) K. P. Feoktistov		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address LINGUISTIC SYSTEMS, INC. 116 AUSTIN STREET CAMBRIDGE, MASSACHUSETTS 02139		11. Contract or Grant No. NASW-2482
		13. Type of Report & Period Covered TRANSLATION
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of: "Kosmicheskiye korabli", In: Naselennyy Kosmos (Inhabited Space) by B.P. Konstantinov, editor, Moscow, Nauka Press, 1972, peages 216-228.

16. Abstract

The author addresses the main problems of space flight as they relate to the earliest stages of manned space flight and to future space flight. Starting with an analysis of the problems encountered in making the first flights of "Vostok" and "Mercury" spacecraft, the article goes on to examine the problems encountered in the Apollo lunar flights and in future manned flights to Mars. Particular attention is given to the division of labor between automatic equipement and human crew.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	UNCLASSIFIED - UNLIMITED

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	~~17~~ 19	$3.00

NASA TT F-14,916

SPACESHIPS

K. P. Feoktistov[†]

In this article I wish to throw light upon three problems: the immediacy of the problems of creating a spaceship and an artificial "living" being on spaceships of the future and on the distribution of responsibilities in ship control between automatic equipement and crew. /216*

A new region of technology arises in our eyes -- spaceship technology. This was begun at the end of the fifties with the building of the first spaceship "Vostok", and then the ships "Mercury," "Voskhod" and "Gemini". Comparatively simple from the point of view of engineers of the end of the fifties and the beginning of the sixties, perhaps, and plainly primitive, these ships already contain the fundamental features which are characteristic for future spacecraft.

The building of a spaceship is a complex and multi-sided problem. In formulation it is similar to the problem of creating some highly organized creature intended to live and work in a very wide range of environmental and spatial conditions. To be sure, it would be possible to find other more inoffensive analogies -- like an ocean ship, an airliner, and so forth, but it seems to me to be simpler to explain the difficulties and scope of the problem in this way.

What are the characteristic features of a living being?

*Numbers in right hand margin indicate pagination in foreign source.

[†]Soviet Pilot-Astronaut, Doctor of Engineering.

- obtaining and analyzing information, exchange of information with other creatures and correspondingly, the presence of organs for obtaining information (eyes, ears, touch, smell, taste) and its analysis (the central and peripheral nervous systems).

- the possibility of existence in a wide range of environmental conditions with the simultaneous maintenance within the organism of the very stable conditions necessary for reliable functioning of the organism, and correspondingly the presence of organs providing for stable conditions with the organism (organs controlling the heat exchange through the skin, blood circulation and so forth).

- a capacity for orientation and motion in space and correspondingly the presence of organs controlling orientation (eyes, the stimulus apparatus, and so forth) and motion (legs, wings and so forth).

- feeding, that is, the capacity for making up for energy losses.

- the presence of a certain excess or reserve of forces in case of unexpected circumstances, the capacity for combatting illnesses and restoring health even after significant traumas and diseases and the presence of reserve strength which is often manifested in games and in other activity not directed towards obtaining primitive material goals.

- Automatic coordination and synchronization of the operation of the internal organs. /217

The characteristic features of a spaceship are as follows:

- Obtaining and analyzing information on the surrounding space, on its position in space (angular and linear coordinates) and on the parameters of motion. The capacity for collecting "new" information and correspondingly the presence of "organs" for obtaining it (measuring devices, optical and gyroscopic devices, radio instruments for scientific research and so forth) and of analyzing information (onboard computers and crew).

- flight in a wide range of conditions (g-force and vibration during liftoff from earth and during reentry, the high temperature of reentry, the vacuum in orbital flight, the flux of light energy from the sun and its absence in the shade of the planet, radiation, meteorites and so forth) and correspondingly, means for maintaining stable conditions within the ship—temperature, pressure, gas composition necessary for life support of the crew and for the operation of onboard apparatus (air tightness of sections, heat shield, means for controlling the heat conditions and gas composition in the cabin, and so forth).

- the presence of maneuverability necessary for changing the direction and nature of motion and correspondingly, the presence of devices for controlling the angular orientation of the ship in space (optical, gyroscopic, radio and other equipment with computing devices and systems of controls—microjet engine, flight wheels and so forth) and means of changing the ship's momentum (correcting engines, rocket stages, electric rocket engines in interplanatary spaceships).

- providing the crew with food, water and oxygen and also supplying the onboard apparatus with energy and correspondingly, the presence onboard either of power reserves or of means of generating energy and of providing for the partial or complete regeneration of supplies required by the crew.

- the presence of reserve strength of construction, duplication of apparatus, systems and individual elements, the presence of energy reserves exceeding that minimally necessary for achieving the goals set, the regular performance of all types of test operations for the purpose of checking the efficiency of systems and units of the ship and the ship complex as a whole.

- Coordination and control of the operation of onboard systems, regulation of the rhythm of their operation in different flight conditions and in different circumstances—with a change in the flight conditions.

These parallels could be extended but those already enumerated are sufficient for our purposes.

The analogies made here at once make it possible to present the sum of the problems which must be solved and also the outlines of a general solution. However, in addition to the general requirements for a spaceship it is necessary to clearly perceive and precisely formulate the goal which we are pursuing in solving a given problem.

The purposes for making spaceships will change with time /218
and correspondingly, the techniques used in making a ship will also change.

The first spaceships ("Vostok" and "Mercury") had a very narrow and precise goal—that of making it possible for man to make space flights in an artificial satellite orbiting the earth and to investigate the influence of flight conditions on the human organism. Such a formulation of the problem also reduced its solution to several narrow problems:

- launching a manned craft into earth's orbit (the problem of creating a sufficiently powerful and reliable rocket carrier);

- the reentry of the spaceship from orbit to earth and landing (mainly protection from the effects of heat fluxes during reentry into the atmosphere);

- providing for monitoring and control of the ship's flight from earth, since before the first flight it was impossible to be sure that a man could independently control the ship's flight in conditions of weightlessness;

- orientation of the ship in space and communication to it of the correcting (braking) momentum necessary for transfering the spacecraft from earth orbit to a descent trajectory through the depth layers of the atmosphere;

- providing for life support systems for the cosmonaut on board the spacecraft and for the operating conditions of onboard apparatus (to be sure, for a limited period of time—on the order of several days);

- energy supply for onboard apparatus.

The first problem was solved with the use of a powerful multistage rocket.

The problem of protecting the ship's cabin from the effects of great heat flow during reentry was solved with the use of a special heat-reflecting material with which the cabin surface is covered.

Radio aids, developed on the basis of the then available radio aids for measuring the motion telemetry and control parameters, were used for monitoring the flight trajectory, the operation of onboard systems and for control from earth.

For the orientation of the ship "Vostok" and in principal very simple method of orientation of one of the ship's axes on the sun with the use of an optical sun detector, was used. A liquid fuel jet engine was used to provide the correcting (braking) momentum.

A temperature control system was created for maintaining stable temperature conditions in the compartments of the ship, "Vostok". Thermal equilibrium between the energy liberated within the ship (due to the activity of the cosmonaut and the operation of onboard apparatus) and the heat exchange with the surrounding space was maintained with the use of a radiation radiator with a luver by the opening and closing of which it was possible to regulate the amount of energy radiated into space.

Heat was transmitted from the ship's cabin to the radiation radiator with the use of a fluid circulating in a closed circuit.

The temperature in the ship's cabin was stabilized by controlling the heat exchange in a gas-liquid heat exchanger installed /220
in the cabin and connected with the circulating cooling liquid. A regeneration device absorbing moisture, carbon dioxide, harmful gas impurities and liberating oxygen maintains the gas composition in the cabin.

Chemical batteries were used for the energy supply of onboard apparatus.

The solutions of these basic problems, found in making the first spacecraft were quite simple. However, with the increasing complexity future craft these solutions will have to be reexamined and new and more effective ones will have to be found. New problems will be added to these as the missions of spacecraft change.

Thus, in making the "Apollo" craft, designed for landing expedition on the moon, a new series of problems arises:

- launching into earth orbit a spaceship weighing tens of times more than the weight of the first spacecraft. This is necessary for providing the fuel for the rocket stages used in driving the ship to the moon, braking during landing on the moon and for returning to earth.

- providing precise control of the trajectory of the ship's motion (in order to illustrate this problem it is sufficient to name but one figure—in returning to earth the ship must enter a "corridor" 10 to 20 kilometers in width at the altitude of the arbitrary perigee) and for complex maneuvers of the ship near the moon. From the point of view of energetics the following classical scheme of launching an expedition to a planet is optimal: transfer of a ship to a satellite orbit, separation from the ship and descent to the planet of a special cabin with the crew, lifting it back into orbit, closing and docking it with the ship, transfer of the crew into the ship and launching the ship to earth.

FOR FUTURE SPACEFLIGHTS

Various experiments with human participation have been conducted and are being conducted in laboratories. These experiments to a certain degree imitate conditions in the cabin of a spacecraft. Young people in good health were chosen for the experiment. During the experiments they were in an air-tight chamber from 10 to 120 days. During the experiments the people in the chamber were subjected to various combinations of ionizing radiation in small doses, in individual experiments the temperature was raised, noise effects were created, and the effects of a number of other factors was studied.

If in ordinary conditions the human organism depends on the environment, then in a hermetically closed compartment the reverse dependence clearly obtains—the environment changes as a result of the life activity of the organism. Moreover, changes in the environment may also be unfavorable. During the experiments it was established that the skin somewhat loses its protective properties against bacteria. Therefore, the number of microorganisms on the skin significantly increases and there are more microbes in the air. Thus, during one of the experiments after 28 days the number of microbes /221 in the air increased by several times.

Definite changes occurred in the human organism during the experiments. This was particularly clear in the case of experiments lasting 60 and 120 days.

In the initial period of the experiments a retardation process intensified in the cortex of the brâin. The light sensitivity of the eyes and the speed of motor reactions decreased. "The coefficient of useful activity" also decreased. During this time (the first 10 to 13 days) some changes in the operation of the heart began, and night time sleep was disturbed. However, in the following days the organism adapted to the conditions of the new environment and its functions were gradually restored. After leaving the chamber, changes again appeared in the organism.

Three months' test showed that additional purification of the air from bacteria and harmful chemical substances, ultraviolet irradiation of the skin of the people undergoing the experiments, the introduction of a high vitamin content into the food, the use of a special complex of physical exercises and several medications significantly decreased the changes in the organism after leaving the chamber.

The return of the ship into the earth's atmosphere with a second spaceflight velocity (approximately 13.5 kilometers per second instead of 17.5 kilometers per second in the case of reentry from a low earth satellite orbit). This signifies that the heat flows acting upon the ship during its motion in the atmosphere increased by two to three times in comparison with heat flows acting on a ship descending from an earth satellite orbit.

The circle of problems is significantly expanded if we try to imagine spaceships intended for making expeditions, for example, to Mars:

- launching a ship into earth's orbit weighing many hundreds of tons (or assembling it in earth's orbit from individual units of lesser weight launched one after the other).

- This problem is closely connected with the problem of energetics: for driving a ship to Mars, braking near Mars and for returning to earth it is necessary to impart to the ship at various stages of the flight increases in velocity amounting to 15 to 25 kilometers per second (depending on the flight scheme) in comparison with 9 kilometers per second in the case of launching a ship to earth's orbit.

The duration of the flight—and here it is necessary to consider the flight time to Mars, the return time to earth and the holding time in Mars' orbit (or on the planet surface) for a favorable position of Mars and earth relative to one another for returning the ship to earth (this time may take around 1.5 years)—may be estimated as approximately 3 years. With a long expedition the problems of feeding and providing the crew with water and oxygen and supplying onboard systems with energy change qualitatively and the problem of reserves and the reliability of onboard systems and the entire complex of the ship as a whole is greatly complicated.

From the point of view of energetics the optimal scheme of a flight to Mars, as in the case of a flight to the moon, is a scheme with the launching of a ship into Mars' orbit and landing only a special cabin of the ship on Mars and the creation of /222 means of transportation on the planet providing for the possibility of observing it.

The solutions used in making the ship "Vostok" remain the classic example of simplicity and harmony of a level of engineering, serving as a basis for the appearance of the first spaceship. But these same solutions can hardly be retained as standards for the future—the further development of spacecraft technology, the accumulation of experiment and progress in other areas of science and technology will produce more optimal and more reliable solutions. The possibilities here are great. Let us present some examples.

Return to Earth. Here progress is developing in the direction of the creation of devices for controllable (and not ballistic) reentry with the use of aerodynamic lift. This is a matter of significantly decreasing g-forces during reentry and providing for precise landing in specific regions for landing spaceships.

Energy Supply. Lowering the weight characteristics, increasing the service life and increasing color are the main problems of development in this area. In addition to energy supply systems using solar batteries, fuel cells and isotopic thermogenerators, in the future, evidently, nuclear thermogenerators and more complex nuclear power plants will be used.

Trajectory Control. Here we must expect development of autonomous shipboard measurement and analysis devices, using optical television and radio devices for measuring (and using stars and planets as reference bodies) and using onboard electronic computers for analysis.

Providing for Thermal Conditions. In the given case the problem comes down to decreasing the range of temperature variations in the ship's compartment. This makes it possible to use more complex light and compact elements in the apparatus and to increase the reliability of their operations (it is here appropriate to remember that, for example, in a healthy man body temperature is maintained correct within tenths of a degree).

In order to provide for heat control it is possible to use fluid lines equalizing the temperature fields along the shelves and other structural elements of the ship, regulating the optical coefficients of the radiation surfaces and radiators included in the "hot" and "cold" circuits of the heat control system.

Providing for the Activity of the Crews. This problem is particularly severe for extended flights. If in the case of making an expedition to Mars we attempt to solve this problem with regard to the supply of food, water and oxygen, then for an expedition of ten men it would be necessary to carry supplies weighing around 70 tons (this without considering possible delays in the expedition).

The ways to solve these problems are by the regeneration of the supplies used. The problem of water regeneration is comparatively simple; it can be handled by current techniques. More complex, but still fully soluble is the problem of the regeneration of oxygen—here the method of biological regeneration may prove /224 to be valid (for example, with the use of simple algae).

The food problem may be solved with the use of dehydrated foods (with the simultaneous use of water regeneration).

A more radical means of providing for life support of the crew on extended flights is, obviously, the creation onboard of a closed ecological cycle, providing for the cycling of substances during the course of the flight, that is, the practically complete regeneration of food, water and oxygen.

The problem of launching into flight trajectory or the more general problem of the energetics of motion of spacecraft appeared. Here we make a distinction between the spacecraft and the rocket type of carrier. Why? To be sure, the ship begins its flight from the moment of launch, from the moment of leaving the earth, and in this section of flight the system "rocket-ship" is a whole. Is it possible that this is a matter of different energy consumptions on different sections of the flight? However, ready for a spaceship on a lunar expedition starting from earth orbit the total increase in velocity on all sections of the flight must be approximately equal to the total velocity imparted to the ship in launching it into earth's orbit, and for a Martian ship—even significantly greater.

The difference between these concepts is explained by the level of development of rocket and space technology. Contemporary space complexes significantly change during their flight from the point of launch from earth to their return: in the section of insertion into earth's orbit the stages of the rocket carrier are successively separated and then the ship is separated from the last extended rocket stage. In returning to earth before reentry to the atmosphere the spaceship itself separates into two or more parts, of which only one cabin (or, as it is called, the descent vehicle) with the crew reaches the earth's surface, discarding even more elements before landing. Thus, if a system weighing 100 tons lifts off from the earth's surface, then a descent vehicle weighing around 1 ton returns. 1:100—this ratio most clearly shows how greatly the system changes from launch to return. Indeed, for lunar for Martian ship using chemical rockets, these ratios may increase to 1:1,000 and even to 1:10,000.

Is this good? This brings up an analogy with complex irreversible transitions which several members of the animal world undergo during the course of their life: a flying insect, an egg, a caterpillar, a pupa, and so forth. During such transition the safety of such beings sharply decreases, which is completely natural. It is interesting to note that in nature those life forms with complex transitions have not acquired a dominant position: evidently, they are less adaptable than other living creatures which do not change in stages during the course of their life.

It must be remarked that in contemporary space systems such transitions are not always reliable, which is explained by the complexity, instability and irreversibility of the processes occurring during the transition. If we plot the probability of "mishaps" during the course of the flight we discover peaks at the places of transitions. The main factor is the irreversibility and impossibility of repetition of the most complex processes. /225

These ideas come to mind: is it impossible to imagine a ship capable of starting directly from earth, entering space flight, landing on other planets and returning to earth without casting off the greater part of its structure during flight, and capable of doing this several times (well, perhaps, with appropriate repairs and after performing the necessary preventive maintenance)? This would make a ship more reliable and it could be checked before "extended" flight.

Two courses of development are possible here and, evidently, both of them will be tested.

The first course is the creation of orbital ships intended for orbital flights around planets and for flights between these orbits. Such ships could be provided with electric jet engines (plasma or ion engines) with very high specific parameters — with a specific thrust (ratio of engine thrust to consumption of the working body per second) on the order of 10,000 to 15,000 units. Such engines, evidently, will use nuclear reactors as a energy source, although it is also conceivable to use solar generators with huge surfaces.

Unfortunately, electric jet engines have very low thrusts — on the order of kilograms or tens of kilograms, and therefore they may only be used in the case of moving on orbit. A characteristic feature of the flight of such ships will be the very long periods of operation of the engine. For example, the operating time of an electric jet engine in driving a ship from earth orbit to Mars or Venice will last for weeks. Therefore, the service life of such engines will scarcely be the main problem in making them. Orbital craft with electric jet engines will practically not vary in flight. In developing the technology of this type of spacecraft, it is possible that spacecraft of the type used at the present time will be used for taking a crew from earth to such an orbital craft and for returning to earth.

The second course of development is the creation of spaceships which change little during the course of the flight from their launching from earth until their return. Such ships may be built on the basis of gas nuclear reactors using all the power of onboard reactors in the sections of flight where high thrusts are required (launching from the surface of a planet) and using hydrogen as a working body. The specific thrust of such engines should be on the order of 3,000 units. For movement between planatary orbits on such ships, it is possible to use electric jet engines as more efficient. It is possible, however, that it will prove useful to use high thrusts for movement between planets, so if it is possible to create engines with higher specific parameters (this will make it possible to shorten the time of interplanatary flights).

<u>The general problem of control.</u> Above we spoke about the basic control functions of a spaceship. /226

At the present time there are already means of almost completely automating the monitoring and control processes on ships (otherwise, it would be impossible to send automatic interplanatary stations to Mars and Venus and it would have been impossible for the first spacecraft to make pilotless flights). Indeed, it must be noted, that a serious analysis of the condition of a spacecraft and its systems at the present time can only be performed by specialists on the ground on the basis of radio telemetry instruments. There is no doubt that it is possible to fully and perfectly reliably automate all control processes on a spacecraft, including the problems of monitoring and analyzing the condition of the craft and its systems.

But then, what role does a man have in controlling a spacecraft? In order to answer this question we will examine one of the characteristic control functions—the control of a ship's orientation with pilot participation.

Pilot control of ship orientation is performed by the combined operation of the following units: sensing elements, determining the angular position of the ship in space (for /227 example, optical sensors, converting a measured deviation into an electrical signal); sensing elements determining the angular velocity of the ship, again yielding a result in the form of an electrical signal; indicator devices—instruments, showing the pilot the value of the measured signals; control sticks, transforming the motion of the pilot's arms into electrical signals; amplifying electrical signals; amplifying-computing-transforming devices, transforming electrical signals from the control sticks into power motions of the control element; control elements (for example, microjet engines).

It turns out that a man in this sequence of working elements essentially performs a very primitive role of a computing unit, converting information obtained into a control signal. And this is actually the case.

Is it possible that a man can replace other elements? As a rule—no. The requirements for the accuracy of control of a spaceship are so high that control "by eye" is possible only in the most simplest cases. Certainly, this does not mean that /228 the control contour cannot or should not include a man. But control can in no way be the main task of a man on board—where he can be successfully replaced by a simple computer.

It is possible to consider the problem of another important control function—the control and analysis of the state and operation of onboard apparatus and systems. Before we try to maintain that this is the function and duty of the crew, it is necessary to recall that dozens of specialists work in deciphering telemetry data, all transmitted to earth from on board the spacecraft during its flight. Certainly, in the spacecraft of the future, the process of analyzing information on the state of the ship and its systems may be performed onboard. But, necessarily by people? Indeed, even on ships with a large crew the greater part of its time and energy will be expended in analyzing this information (the voltage, supply, proper functioning as regards results and pickup times of the numerous instruments and units, of regulation of all types of dynamic processes—gas composition, thermal conditions of the compartments and individual surfaces and units of the ship, the power supplied into the ship's circuits, orientation of the ship and so forth). It is clear that the reliability of the crew's analysis of the state of the ship is increased if the crew is freed from the primitive but very numerous functions of primary analysis of information, which can be successfully performed by the simplest analog automatic control devices and electronic computers.

Hence the following distribution of responsibilities for control appears logical.

Automatic control systems—measuring, regulating dynamic processes and operating rhythms, primary and overall control of the state of the ship and its systems and providing the crew with analyzed information in general form; for example, "okay" or "okay, except"; monitoring the states of individual systems with the valuation "good", "bad"; determining the state of the parameters and functioning of individual systems (on demand of the crew); making recommendations for further acts by the crew; prognosis of the operation and state of systems and so forth.

Crew—selecting and making solutions on the further course of operations on the flight on necessary preventive measures and so forth—in a word, the crew must retain the "right of choice". Finally, in case of emergency the crew must be able to obtain primary information. But its analysis is not a regular function but an exceptional matter.

The crew should not be assigned the greatest problems of control for otherwise it would have no time for anything else. Indeed, in such case, control of the ship would become an end in itself.

Obtaining new information, analyzing it and on the basis of this analysis to again obtain new information is the main task of spacecraft crews.